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(54) **Apparatus for optically scanning a radiation-reflecting information plane.**

(57) An apparatus is described for optically scanning an information plane (2) in which a radiation beam (b) emitted by a diode laser (4) is focused by a lens system (6) on the information plane and the radiation reflected by this plane is focused, via a composite diffraction grating (9), into two radiation spots (V_1, V_2) each cooperating with a separate detector pair (18, 19; 20, 21). The separating strips (22, 23) of the detector pairs are parallel, thus providing fairly wide tolerances in the positions of the elements (9, 20) while the apparatus is satisfactorily corrected for wavelength variations of the radiation beam (b).

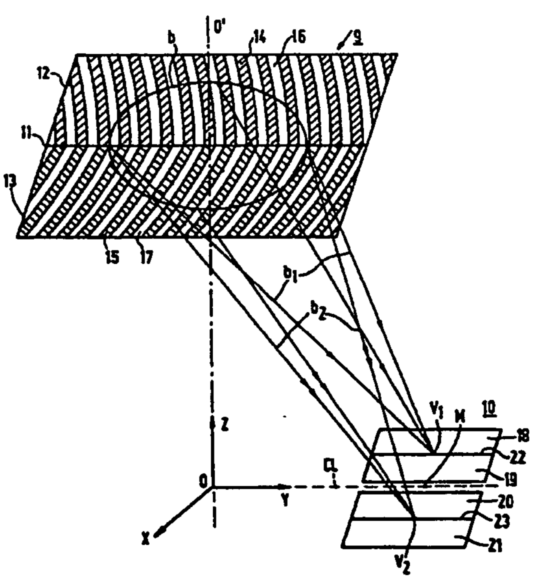

FIG.2

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Apparatus for optically scanning a radiation-reflecting information plane.

The invention relates to an apparatus for optically scanning a radiation-reflecting information plane, which apparatus comprises a diode laser supplying a scanning beam, an objective system for focusing the scanning beam to a scanning spot in the information plane and for re-imaging the scanning spot on a composite radiation-sensitive detection system, and a composite diffraction element arranged in the radiation path between the diode laser and the objective system for deflecting a part oi the radiation beam reflected by the information plane towards the radiation-sensitive detection system and for splitting the diffracted beam into a plurality of sub-beams constituting a corresponding plurality of radiation spots on a corresponding plurality of detector pairs of the composite detection system, the separating strips between two detectors associated with one detector pair having such an orientation that displacements of the re-imaged radiation spots resulting from wavelength variations of the scanning beam do not have any influence on the detector signals.

An apparatus of this type, which is in principle suitable for reading information recorded in an optical record carrier and for optically inscribing such a record carrier is known from United States Patent No. 4,665,310. In this apparatus the composite diffraction element, in the form of a diffraction grating, fulfils two functions for which otherwise two separate elements must be used. In the first place the grating ensures that the radiation reflected by the information plane and passing through the objective system is diffracted from the path of the radiation emitted by the diode laser so that a detection system can be placed in the path of the reflected radiation. In the second place the grating splits the reflected beam into two sub-beams which are required for generating a focusing error signal, i.e. a signal comprising information about the magnitude and the direction of a deviation between the focusing plane of the objective system and the information plane. A separate detector pair is associated with each sub-beam, the difference between the output signals of the detectors associated with the same pair being a measure for the degree of focusing of the scanning beam on the information plane.

In the said record carrier the information is arranged in accordance with information tracks. If the bounding line between the two sub-gratings is parallel to the track direction, a signal comprising information about the magnitude and direction of a deviation between the centre of the scanning spot and the centre line of the iniormation track to be scanned can be obtained by determining the sum of the output signals of each detector pair and by subtracting these sum signals from each other.

To realise the desired beam splitting, the diffraction grating of the apparatus according to United States Patent No. 4,665,310 comprises two sub-gratings having the same grating period, while the grating strips of the first sub-grating extend at a first angle and the grating strips of the second sub-grating extend at a second angle, which is equal but opposite to the first angle, to the bounding line of the two sub-gratings. Since a diffraction grating diffracts an incident beam in a plane transversely of the direction of the grating lines, the beam portion incident on one of the sub-gratings will get a different direction than the beam portion incident on the second sub-grating

As described in United States Patent No. 4,665,310 the grating design described in this document is based on a previously proposed composite diffraction grating. The latter grating comprises two sub-gratings in which the grating strips of the one sub-grating have the same direction as those of the other sub-grating, but in which the grating periods of the two sub-gratings are different. Since the angle at which an incident beam is diffracted by a grating depends on the grating period, the beam portion incident on one of the sub-gratings is diffracted at a different angle than the beam portion incident on the other sub-grating.

Satisfactory experience has been gained with scanning apparatuses comprising these gratings. However, it has been found that when using a grating a deviation in the generated focusing error signal may occur due to a variation in the wavelength of the scanning beam. It is true that this deviation can remain within the range of tolerance laid down for the focusing error signal, but it leaves only little room for possible other deviations. The last-mentioned deviations may occur, for example, due to assembly errors, movements of the optical components with respect to one another or offsets in the electronic processing circuit.

As is known, the wavelength λ of the radiation beams emitted by diode lasers, which are often used in practice, may vary, for example due to temperature variations. Furthermore, the wavelengths of individual diode lasers, which have been manufactured at different instants while using the same process, may be mutually different. A wavelength variation of the scanning beam results in a change of the angles at which the sub-beams are diffracted by the sub-gratings, resulting in a change of the positions of the radiation spots on the detector pairs.

To prevent these changes in position from af-

fecting the generated focusing error signal, it has been proposed to arrange the separating strips of each detector pair in such a way that the displacement of the radiation spots due to the wavelength variations occurs along these separating strips.

In the apparatus described in United States Patent No. 4,665,310 these strips are effective, that is to say when projected on the composite grating, transverse to the grating lines of the associated gratings. If the detector pairs are located on one side of the optical axis of the objective system and in one plane which is perpendicular to this optical axis and coincides with or is parallel to the radiation-emitting surface of the diode laser, the separating strips will extend at equally large but opposite angles ($+\Psi$, $-\Psi$) to the line which connects the centre of the two detector pairs to the centre of the radiation-emitting surface of the diode laser. Such a measure can also be taken in an apparatus comprising a diffraction grating whose sub-gratings have different grating periods, while the directions of the grating strips of the two sub-gratings are equal.

When using the composite detector with oblique separating strips, the distance, measured along the said bounding line, between the centre of the two detector pairs and the centre of the radiation-emitting surface of the diode laser must be adjusted very accurately.

It is an object of the present invention to provide an apparatus of the type described in the opening paragraph which is corrected for wavelength variations and which provides wider tolerances for the positions and parameters of the optical elements, as compared with other apparatuses.

The apparatus according to the invention is characterized in that the separating strips of the detector pairs are in principle parallel to a line which connects the centre of the radiation-emitting surface of the diode laser to the centre of the composite radiation-sensitive detection system.

The present invention is based on a novel design concept for the said scanning apparatus. Hitherto, an end configuration relating to the positions and the parameters of the elements of the apparatus, with the exception of the composite detector, was chosen and a composite detector was then designed with such a geometry, notably such an angle Ψ of the separating strips, that the apparatus was corrected for wavelength variations. The apparatus according to the present invention is designed by firstly designing a composite detector with a given geometry, starting from a rough set-up of the apparatus, which detector is optimized for wavelength variations and position tolerance. Subsequently the design of the apparatus is finished, using the wider tolerances provided by the composite detector for the other parameters, notably the position of various optical elements.

The invention can be used in scanning apparatuses in which the diffraction element is constituted by a grating comprising a plurality of sub-gratings.

The sub-gratings may have straight grating strips and a constant grating period.

Preferably, the apparatus is, however, further characterized in that the sub-gratings have a varying grating period and in that the grating strips are curved.

When using a diffraction grating having a varying grating period, less stringent requirements need to be imposed on the accuracy of positioning the diode laser relative to the detectors in the form of photodiodes, which is particularly important if the height of the apparatus measured along the optical axis of the objective system must be reduced. Moreover, when using gratings with curved grating strips, it is possible to correct for imaging errors such as coma and astigmatism by adapting the curvatures of the composite grating, which errors may occur when using a diffraction grating with straight grating strips.

A preferred embodiment of the apparatus is characterized in that the two sub-gratings have the same average grating period, while the main directions of the grating strips of the first sub-grating extend at a first angle and those of the grating strips of the second sub-grating extend at a second, opposite angle to the bounding line of two sub-gratings, and in that the detector pairs are juxtaposed in a direction transversely of the direction of the said bounding line.

A second embodiment of an apparatus, in which the composite grating comprises two sub-gratings, is characterized in that the grating strips of the one sub-grating have the same main direction as those of the other sub-grating, in that the average grating periods of the sub-gratings are different, in that the detector pairs are juxtaposed in a direction parallel to the bounding line between the sub-gratings and in that the separating strips of the detector pairs are located on the said connection line.

This embodiment is not complete, but to a great extent, corrected for variations in the wavelength of the scanning beam, which may be sufficient under circumstances. For a full correction, the separating strips of the detector pairs must extend at equal but opposite angles of the order of 0.1° to the said connection line. This situation is considered to be within the concept that the separating strips of the detector pairs are in principle parallel to the connection line.

A third embodiment of the apparatus is characterized in that the main directions of the grating

strips of the first sub-grating extend at a first angle and those of the gratings strips of the second sub-grating extend at a second, opposite angle to the bounding line between the sub-gratings, in that the average grating periods of the two sub-gratings are different and in that the detector pairs occupy different positions in a direction which is both parallel and perpendicular to the said bounding line.

Embodiments of the invention will now be described in greater detail with reference to the accompanying drawings in which

Fig. 1 shows diagrammatically an embodiment of a read apparatus comprising a diffraction grating,

Fig. 2 is a perspective diagrammatical view of a first embodiment of the detection system according to the invention and the associated diffraction grating,

Figs. 3a and 3b show the variations of the radiation spots in a known detection system when focusing errors occur,

Fig. 4 shows the radiation-sensitive detection system used in the apparatus according to Fig. 2,

Fig. 5 is a basic diagram of the apparatus, in which the adjustable parameters have been indicated,

Fig. 6 shows a second embodiment of the detection system and the associated diffraction grating,

Fig. 7 is an alternative to the detection system of Fig. 6, and

Fig. 8 shows a third embodiment of the detection system and the associated diffraction grating.

In Fig. 1 a small portion of an optical record carrier 1 with a radiation-reflecting information plane 2 is shown in a tangential section. This Figure shows one of the tracks 3 located in the information plane 2. Such a track comprises information areas 3a alternating with intermediate areas 3b. The areas 3a may for example be located at a different height than the intermediate areas 3b. The information surface is scanned by a beam b emitted by a diode laser 4. This beam is focused to a small scanning spot V in the information plane by an objective system 6, schematically represented by a single lens. The objective system may be integrated with a collimator lens, as is shown in Fig. 1. Alternatively, a separate collimator lens may be arranged in front of the objective system. As the record carrier is rotated about an axis 8, which is parallel to the optical axis $00'$, a track 3 is scanned and the read beam is modulated by the information contained in this track. The entire information surface is scanned by moving the record carrier and the read head, comprising the source 4, the objective system 6 and the detection system 10, in a radial direction, or X direction relative to one another.

The beam which has been reflected and modulated by the information surface should be detected, so that this beam must be separated from the ongoing beam. Therefore, the apparatus should comprise a beam-separating element.

For reading an information structure with minute information details, for example of the order of 1 μm, an objective system having a large numerical aperture is required. The depth of focus of such an objective system is small. Since variations in the distance between the information plane 2 and the objective system 6 may occur which are larger than the depth of focus, steps have to be taken in order to detect these variations and, in response thereto, correct the focusing. To this end the apparatus may be provided with a beam splitter which splits the reflected beam into two sub-beams, and with, for example, two detector pairs a first pair of which cooperates with the first sub-beam and the second pair cooperates with the second sub-beam. The output signals of the detectors are processed to form, inter alia, a focus-servo signal.

As described in the Article "optische Fokusfehlerdetektion" in "Neues aus der Technik" No. 6, December 15, 1980, page 3, beam separation and beam splitting can be effected by means of a single element, namely a transparent grating. This grating splits the beam reflected by the information plane 2 and passing through the objective system 6 into a non-diffracted zero-order sub-beam and a plurality of first-order and higher order sub-beams. One of these beams, preferably a first-order sub-beam, is incident on the radiation-sensitive detection system 10 and is used for generating, inter alia a focusing error signal. The grating parameters, notably the ratio between the width of the grating strips and that of the intermediate grating strips and the depth and the shape of the grating grooves, may be chosen to be such that a maximum quantity of radiation reaches the detection system.

Fig. 2 shows in a perspective elevational view a first embodiment of the radiation-sensitive detection system 10 according to the invention and the associated grating. The beam b is shown by way of its cross-section at the area of the grating 9. This grating 9 comprises two sub-gratings 12 and 13 separated from each other by the line 11. The grating strips of the sub-gratings are denoted by the reference numerals 14 and 15, respectively. These grating strips are separated by intermediate strips 16 and 17. In this embodiment the sub-gratings have the same grating periods, but the main directions of the, preferably curved, grating strips 14 of the sub-grating 12 extend at a first angle to the bounding line 11, while the main

directions of the curved grating strips 15 of the second sub-grating 13 extend at a second, preferably equally large but opposite angle to the bounding line. The sub-beams are substantially diffracted in a direction transversely of the main directions. Since the main directions are different, the sub-beams b_1 and b_2 are diffracted at different angles in the XZ plane. This means that in the plane of the detectors, the XY plane, the radiation spots V_1 and V_2 are displaced relative to each other in the X direction. In this Figure and in the other Figures the references X, Y and Z are the axes of a system of coordinates whose origin 0 coincides with the centre of the radiation-emitting surface of the diode laser 4.

Radiation-sensitive detectors in the form of photodiodes 18, 19 and 20, 21 which are separated by narrow strips 22 and 23 are associated with each of the sub-beams b_1 and b_2, respectively. These detectors are positioned in such a way that in the case of a correct focusing of the beam b on the information plane 2 the intensity distribution of the radiation spots V_1 and V_2 formed by the sub-beams b_1 and b_2 is symmetrical relative to the detectors 18, 19 and 20, 21, respectively. When a focusing error occurs, the radiation spots V_1 and V_2 will become asymmetrically larger, as is shown in Figs. 3a and 3b. These Figures show a known composite detector, i.e. a detector whose separating strips 22 and 23 extend at an angle $+\Psi$ and $-\Psi$, respectively to the connection line CL between the point 0 and the centre M of the oomposite detector 10, which connection line coincides with the separating strip 24 between the detector pairs 18, 19 and 20, 21 in Figs. 2 and 3. In Fig. 3a shows the situation when the focus of the beam b is in a plane in front of the information plane 2, while Fig. 3b relates to the situation when the focus of the beam b is in a plane behind the information plane.

If the output signals of the detectors 18, 19, 20 and 21 are represented by S_{18}, S_{19}, S_{20} and S_{21}, respectively, the focusing error signal S_f will be given by:

$S_f = (S_{18} + S_{21}) - (S_{19} + S_{20})$.

A signal which is proportional to the information being read, or the information signal S_i is given by:

$S_i = S_{18} + S_{19} + S_{20} + S_{21}$.

If the bounding line 11 of the two sub-gratings 12 and 13 is parallel to the direction of a track 3 being read, it is also possible to generate a tracking error signal S_r by means of the detector signals. This signal is given by:

$S_r = (S_{18} + S_{19}) - (S_{20} + S_{21})$.

The apparatus can be dimensioned such and the geometry of the composite grating and the wavelength of the scanning beam can be adapted to one another in such a manner that the sub-beams b_1 and b_2 are focused on the separating strips of the photodiode pairs 18, 19, 20 and 21 if the plane in which the scanning beam b is focused coincides with the information plane 2. Then the magnitude of the radiation spots V_1 and V_2 is minimal and the intensity distribution of each spot is symmetrical relative to the associated detector pair.

When varying the wavelength of the scanning beam, the angles at which the sub-beams are diffracted by the sub-gratings will vary. This means that for each sub-beam the position in which the chief ray of this sub-beam is incident on the associated photodiode pair is displaced. To ensure that this displacement of the chief ray does not have any influence on the focusing error signal, it is already ensured in the known apparatuses that this displacement occurs along the separating strips 22 and 23 of the detector pairs. In a previously proposed embodiment separating strips 22 and 23 therefore extend at such an angle $+\Psi$ and $-\Psi$ to the connection line between the points M and O that the extensions of the separating strips intersect each other at the optical axis $00'$ as is shown in Figs. 3a and 3b. For the sake of clarity the angles Ψ are exaggerated in these Figures. If the plane of the composite detector coincides with the radiation-emitting surface (XY) of the diode laser 4, these extensions intersect each other at the point O.

If the separating strips extend at an angle Ψ to the connection line CL, the position of the composite detector in the Y direction should be adjusted accurately. When the distance Y_d between the points M and O varies the positions of the separating strips relative to the radiation spots V_1 and V_2 also vary so that such a variation will influence the focusing error signal. It is true that, when using a composite grating 9 with curved grating strips, the positions of the radiation spots V_1 and V_2 can be corrected by displacing this grating but such a correction can only be carried out to a limited extent.

Moreover, when using a composite detector 10 with oblique separating strips, stray light, which may be produced in the apparatus by, for example, false reflections, may affect the different detector signals in an unequal manner so that the focusing error signal being derived is influenced by this stray light. Such a beam of stray light will in fact be incident on one part, for example the left-hand part of the composite detector 10, as is illustrated by means of the broken-line arc of a circle SL in Fig. 3a. The portions of the separate detectors located within this arc of a circle have different sizes so that the stray light contributions to the detector output signals will be different for the different detectors.

Furthermore, if the separating strip 22, 23 in a detector pair 18, 19; 20, 21 varies in such a way

that the detectors of this pair have unequal sizes, not only a first zero which corresponds to the desired focusing may be produced in the curve representing the variation of the focusing error signal as a function of the focusing error, but also a second zero may be produced which does not correspond to the desired focusing. Then these is a risk that the focus-servo system of the apparatus adjusts the focus of the scanning beam above or below the information plane 2.

According to the invention the detector geometry shown in perspective in Fig. 2 and in a plan view in Fig. 4 is used.

In the composite detector 10 of Fig. 4 the angle Ψ is equal or substantially equal to zero; in other words, the separating strips 22 and 23 are parallel to each other and to the separating strip 24 and the connection line CL. A less stringent requirement is then to be imposed on the distance Y_t between the points M and O. Moreover, the apparatus is then less sensitive to a tilt of the composite detector 10 about the Y axis.

In Fig. 4 the reference symbol W denotes the overall width of the composite detector 10 and S denotes the nominal distance between the radiation spots V_1 and V_2 in the plane of the detector 10. The nominal distance S is the distance between the positions occupied by the radiation spots V_1 and V_2 if the scanning beam is sharply focused on the information plane 2. The two detector pairs 18, 19 and 20, 21 can be arranged against each other but also at some distance from each other, as is shown in Fig 4 and Fig. 2, respectively. The following considerations play a role in the design of the composite detector 10.

With a view to optimum detector signals, it is desirable for the different detectors to have the same size. If the detector pairs are arranged against each other, this means that W = 2S. The values of W and S are the result of a compromise. On the one hand, the width of the detector 10 should be as small as possible in order that a minimum possible quantity of stray light will reach the composite detector. On the other hand W should be as large as possible in order that the focusing error detection system has a maximum possible capture range. For S it holds that its value should not be too small because interference phenomena may then occur between the radiations of the radiation spots V_1 and V_2. In fact, these spots are not punctiform, sharply defined spots but are somewhat extended with an intensity decreasing from the centre to the exterior. On the other hand S should not be too large because later on, in the further design of the apparatus, it may appear that such displacements in, for example the X and Y directions, of optical elements, for example the grating 9, should be carried out so that aberrations may occur, resulting in the slope of the focusing error signal curve around zero becoming smaller.

An advantage of the composite detector with parallel separating strips may be that this detector can more easily be made with the required accuracy, particularly with respect to the distance S, as compared with a detector having oblique separating strips.

Fig. 5 shows the parameters between which, with the choice for Ψ = 0 being made, a choice can still be made to obtain the desired optimization of the apparatus. In this Figure the centre of the radiation-emitting surface of the diode laser 4 is considered to be located in the origin 0 of the system of coordinates X Y Z. Y_d and Z_d are the distances along the Y and Z axes between the centre M of the detector 10 and the point 0. In principle, these distances can be freely chosen. In practice a combination of a diode laser and a photodiode will mostly be used, which elements are mounted on one block so that the choices for Y_d and Z_d are limited. Preferably by displacing the grating 9 along the X and Y axes and rotating it about the Z axis it can be ensured that the radiation spots V_1 and V_2 occupy the desired positions on the composite detector 10.

Fig. 6 shows a second embodiment of the apparatus according to the invention. The main directions of the preferably curved grating strips of the two sub-gratings 12 and 13 now extend at the same angles to the bounding line 11, while the average grating periods of the two sub-gratings are different. Consequently, the angle at which the sub-beam b_2 is diffracted in the YZ plane is different from the angle at which b_1 is diffracted. This means that the radiation spots V_1 and V_2 are displaced relative to each other in the Y direction in the plane XY of the detectors.

As far as its operation is concerned, the apparatus according to Fig. 6 is largely analogous to that according to Fig. 2 so that it need not be described. If the separating strips 22 and 23 of the detector 10 in Fig. 6 are parallel to each other (Ψ = 0), as is proposed in the present invention, the focusing error signal can be independent of the scanning beam wavelength variation to such an extent that it is acceptable in practice. If it is desired under circumstances to still further reduce this dependence, the bounding lines 22 and 23 can be positioned at a very small angle Ψ_1 of the order of 0.1° relative to the connection line CL between the points M and O, as is shown in Fig. 7. Due to the very small value of the angle Ψ_1 one remains within the scope of the present invention.

It is to be noted that, since the efficiency of a diffraction grating, i.e. the quotient of the amount of radiation diffracted in the desired direction and the total amount of radiation incident on the grating

dependsinter alia on the grating period, the composite diffraction grating according to Fig. 2 is preferred to that according to Fig. 6 or 7. In fact, due to the unequal grating periods of the sub-gratings in the least-mentioned gratings, the sub-beams may acquire unequal intensities so that an offset may be produced in the tracking error signal. This type of offset cannot occur in an apparatus using the diffraction grating of Fig. 2.

Fig. 8 shows a third embodiment of the apparatus according to the invention. Again, the grating 9 comprises two sub-gratings 12 and 13. However, both the grating period and the main direction of the preferably curved grating strips of the two sub-gratings are different. The operation of this grating may be assumed to be a combination of that of the gratings of Figs. 2 and 6. Consequently, the sub-beam b_1 is diffracted by the grating of Fig. 8 both in the XZ plane and in the YZ plane through a different angle than the sub-beam b_2. In the plane XY of the composite detector 10 the radiation spots V_1 and V_2 are displaced relative to each other both in the X and the Y directions. It will be evident that also the detector pairs 18, 19 and 20, 21 in the X and Y directions are displaced relative to each other. According to the invention the separating strips 22 and 23 are parallel to each other, while the apparatus is still satisfactorily corrected for wavelength variations of the scanning beam b.

The invention can be used in any focusing error detection system in which a diffraction element is used for separating the beam reflected by the information plane and the beam emitted by the diode laser and for splitting the reflected beam into a plurality of sub-beams. In practice, two sub-beams are mostly used which are formed by means of two sub-gratings. Under circumstances it may be desirable to use a composite grating having more than two sub-gratings so that more than two sub-beams are formed. The measure according to the invention can be taken for each of the detector pairs associated with these sub-beams. The sub-gratings may be straight grating lines and may have a constant grating period. However, preferably a type of grating, also referred to as holograms, is used, embodiments of which are shown in Figs. 2, 6 and 8. Their sub-gratings have a varying grating period, the variation in the period being, for example of the order of a few percents of the average grating period. Moreover, the grating strips of the two sub-gratings are curved, as is shown in Figs. 2, 6 and 8. Thus, these sub-gratings have a variable lens action. Due to the varying grating period the positions of the radiation spots V_1 and V_2 can be varied by displacing the grating 9 in its own plane. Aberrations in a direction perpendicular to the direction of the bounding line 11 can be minimized by the curvatures of the grating strips.

The possibility of moving the positions of the radiation spots V_1 and V_2 is particularly important if an integrated laser-photodiode unit is used, i.e. a component in which the diode laser and the photodetectors are arranged on one support and are therefore fixed relative to each other and thus have a fixed mutual distance in the Z direction. This distance is subject to manufacturing tolerances and cannot be corrected during assembly of the apparatus by displacing the photodiodes relative to the laser diode in the Z direction.

In the embodiments according to Figs. 6 and 8 it can be ensured that in spite of the different angles at which the sub-beams b_1 and b_2 are diffracted in the YZ plane due to the different average grating periods of the sub-gratings 12 and 13, the foci of the sub-beams are located in one XY plane, namely by giving the grating periods and the curvatures of the grating strips of corresponding portions of the sub-gratings a different variation.

An important advantage of the diffraction grating having curved grating strips as compared with a grating having straight grating strips is that the optical aberrations such as coma and astigmatism, which may occur when using the last-mentioned grating, can be avoided in the first-mentioned grating by taking these aberrations into account when manufacturing this grating and by adapting the curvatures of the grating strips to these aberrations.

The invention has been described for use in a read apparatus, but it may alternatively be used in a write apparatus or in a combined write-read apparatus in which during recording the focusing and the tracking of the write beam are monitored. The focus-error detection system described here does not utilize special properties of the information surface 2. It is merely necessary and adequate that this surface is reflecting. Therefore, the invention may be used in various apparatuses where a very accurate focusing is required, for example in microscopes, in which case the tracking error detection may be dispensed with.

Claims

1. An apparatus for optically scanning a radiation-reflecting information plane, which apparatus comprises a diode laser supplying a scanning beam, an objective system for focusing the scanning beam to a scanning spot in the information plane and for re-imaging the scanning spot on a composite radiation-sensitive detection system, and a composite diffraction element arranged in the radiation path between the diode laser and the objective system for deflecting a part of the radiation beam reflected by the information plane towards the radiation-sensitive detection system and

for splitting the deflected beam into a plurality of sub-beams constituting a corresponding plurality of radiation spots on a corresponding plurality of detector pairs of the composite detection system, the separating strips between two detectors associated with one detector pair having such an orientation that displacements of the re-imaged radiation spots resulting from wavelength variations of the scanning beam do not have any influence on the detector signals, characterized in that the separating strips of the detector pairs are in principle parallel to a line which connects the centre of the radiation-emitting surface of the diode laser to the centre of the composite radiation-sensitive detection system.

2. An apparatus as claimed in Claim 1, in which the diffraction element is a diffraction grating comprising two sub-gratings, characterized in that the sub-gratings have a varying grating period and in that the grating strips are curved.

3. An apparatus as claimed in Claim 1, 2 or 4, in which the diffraction element is a diffraction grating comprising two sub-gratings, characterized in that the two sub-gratings have the same average grating period, while the main directions of the grating strips of the first sub-grating extend at a first angle and those of the grating strips of the second sub-grating extend at a second, opposite angle to the bounding line of the two sub-gratings, and in that the detector pairs are juxtaposed in a direction transversely of the direction of the said bounding line.

4. An apparatus as claimed in Claim 1 or 2, in which the diffraction element is a diffraction grating comprising two sub-gratings, characterized in that the grating strips of the one sub-grating have the same main direction as those of the other sub-grating, in that the average grating periods of the sub-gratings are different, in that the detector pairs are juxtaposed in a direction parallel to the bounding line between the sub-gratings and in that the separating strips of the detector pairs are located on the said connection line.

5. An apparatus as claimed in Claim 1 or 2, in which the diffraction element is a diffraction grating comprising two sub-gratings, characterized in that the grating strips of the one sub-grating have the same main direction as those of the other sub-grating in that the average grating periods of the sub-gratings are different, in that the detector pairs are juxtaposed in a direction parallel to the bounding line between the sub-gratings and in that the separating strips of the detector pairs extend at equal but opposite angles of the order of 0.1° to the said connection line.

6. An apparatus as claimed in Claim 1 or 2, in which the diffraction element is a diffraction grating comprising two sub-gratings, characterized in that the main directions of the grating strips of the first sub-grating extend at a first angle and those of the grating strips of the second sub-grating extend at a second, opposite angle to the bounding line between the sub-gratings, in that the average grating periods of the two sub-gratings are different and in that the detector pairs occupy different positions both in a direction parallel to and in a direction perpendicular to the said bounding line.

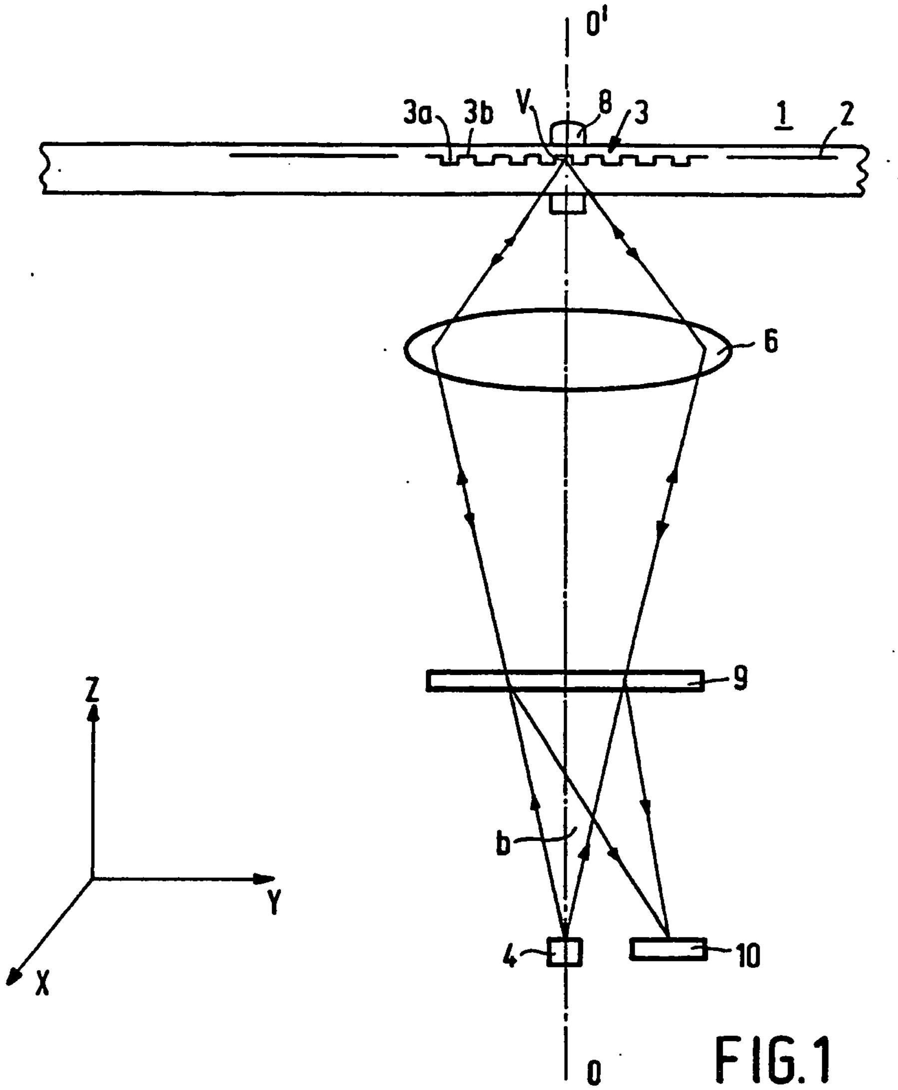


FIG.1

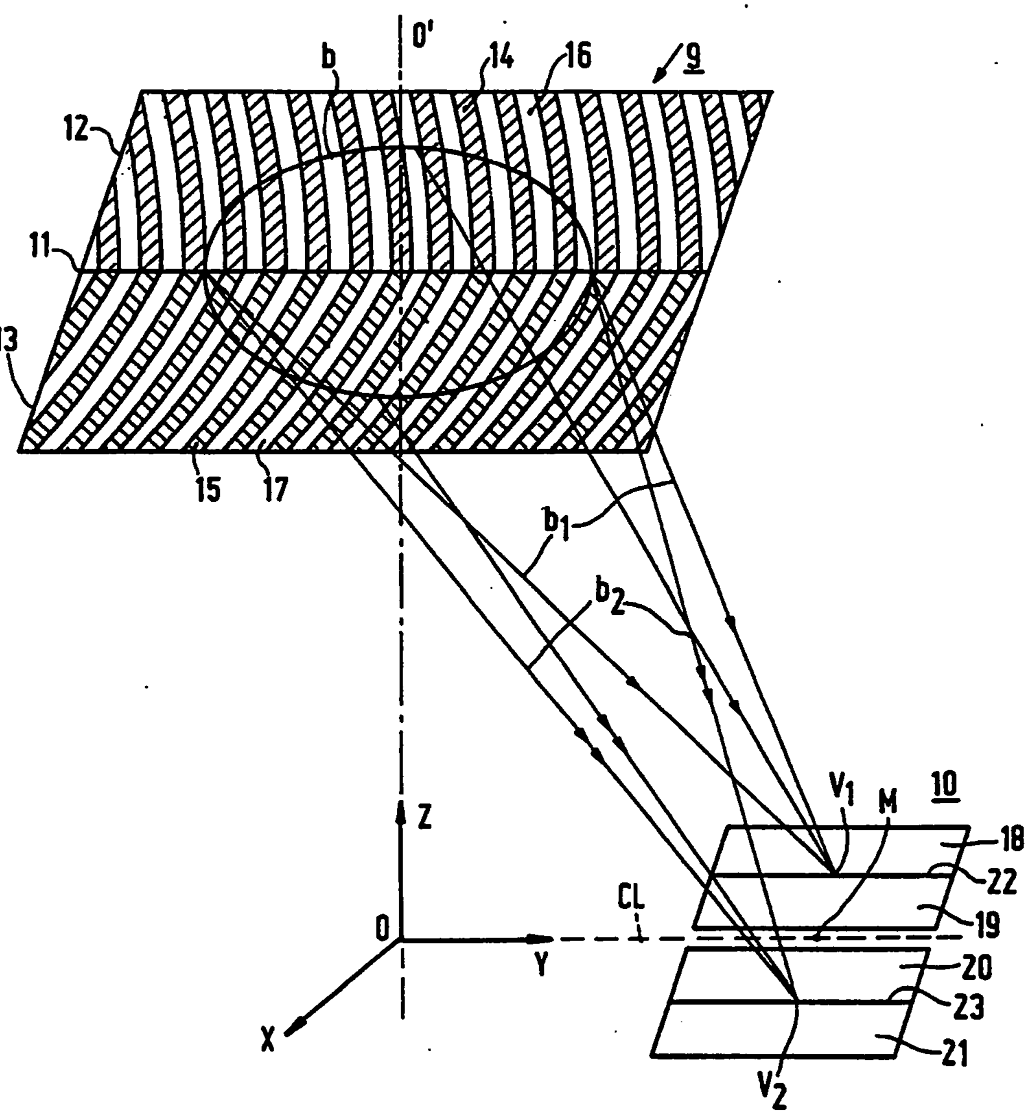


FIG. 2

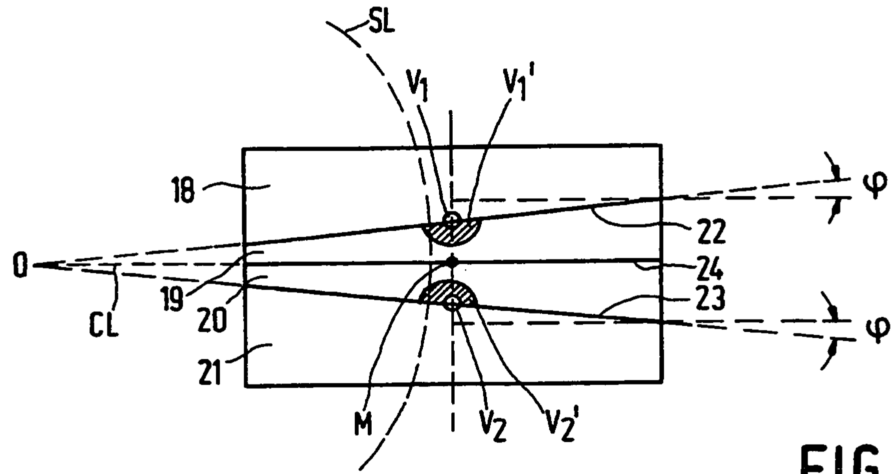


FIG.3a

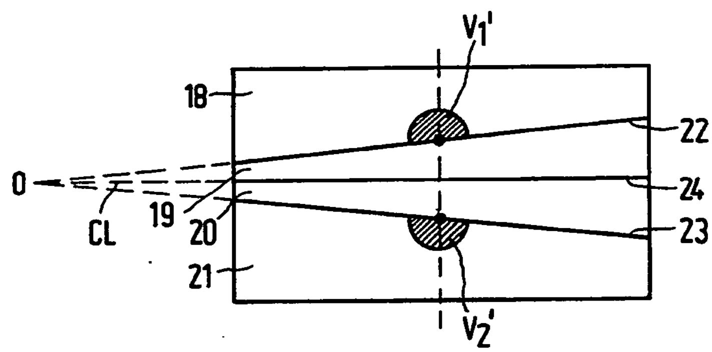


FIG.3b

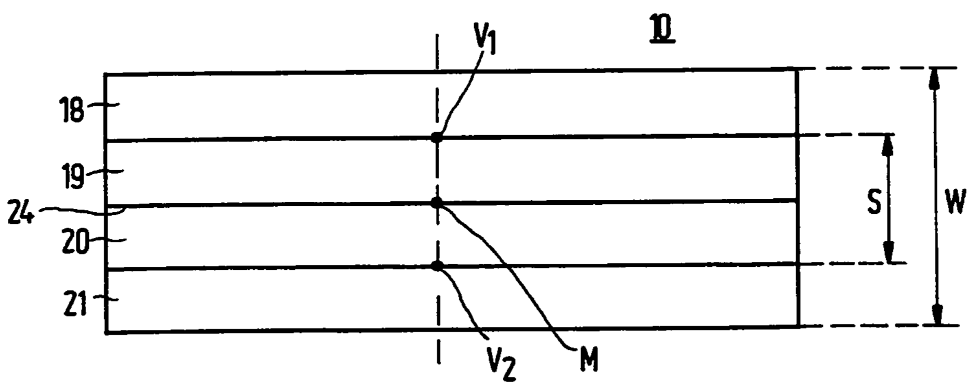


FIG.4

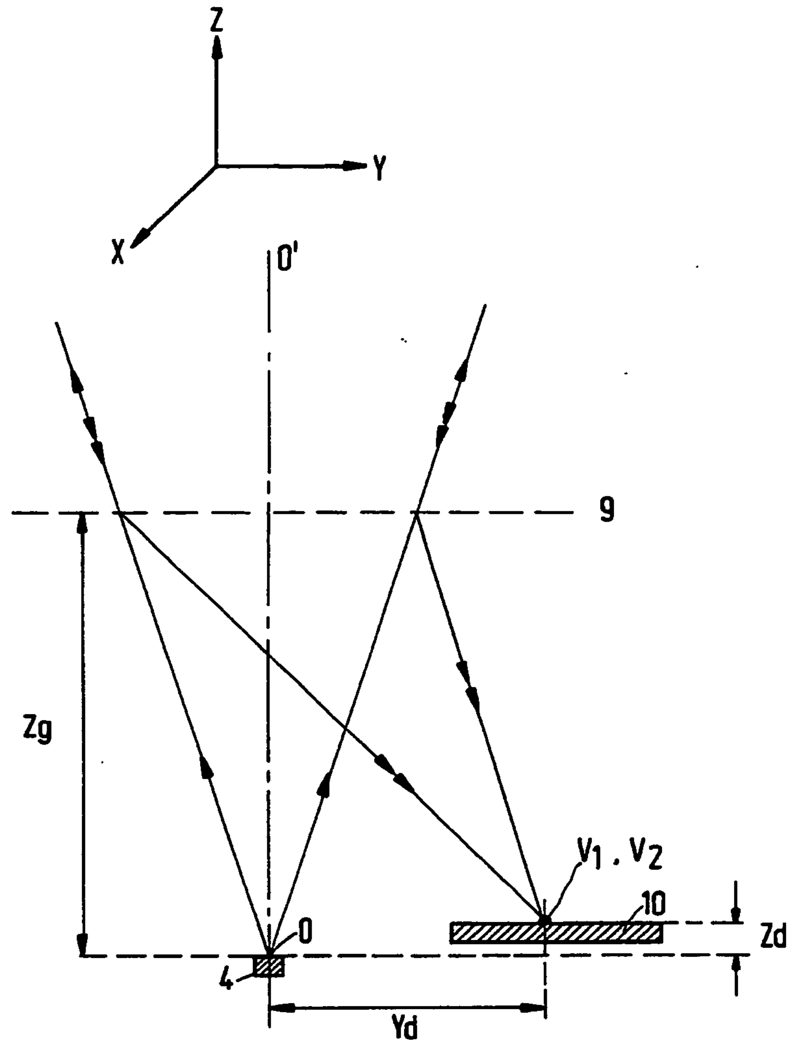


FIG. 5

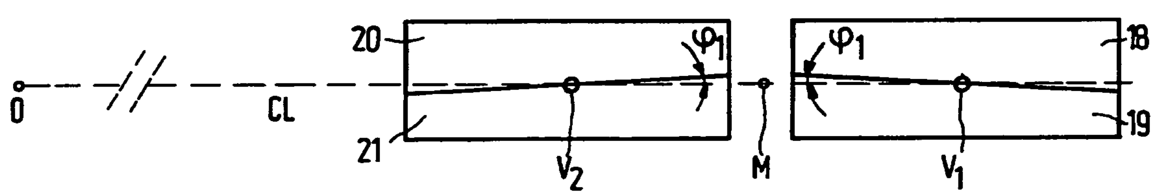
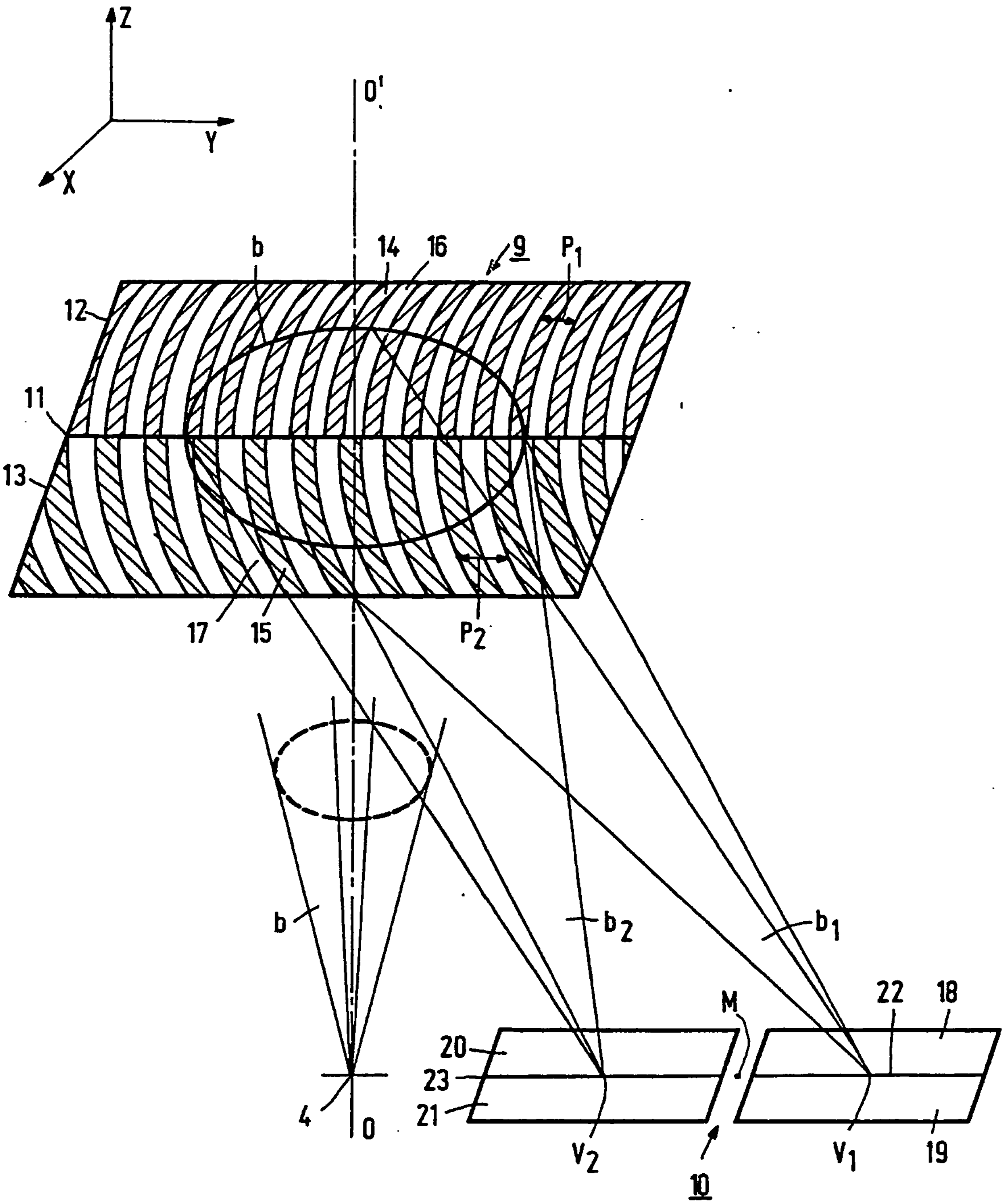


FIG. 7



Z
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9
P1
12
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13
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b1
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V2
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V1
19

FIG.6

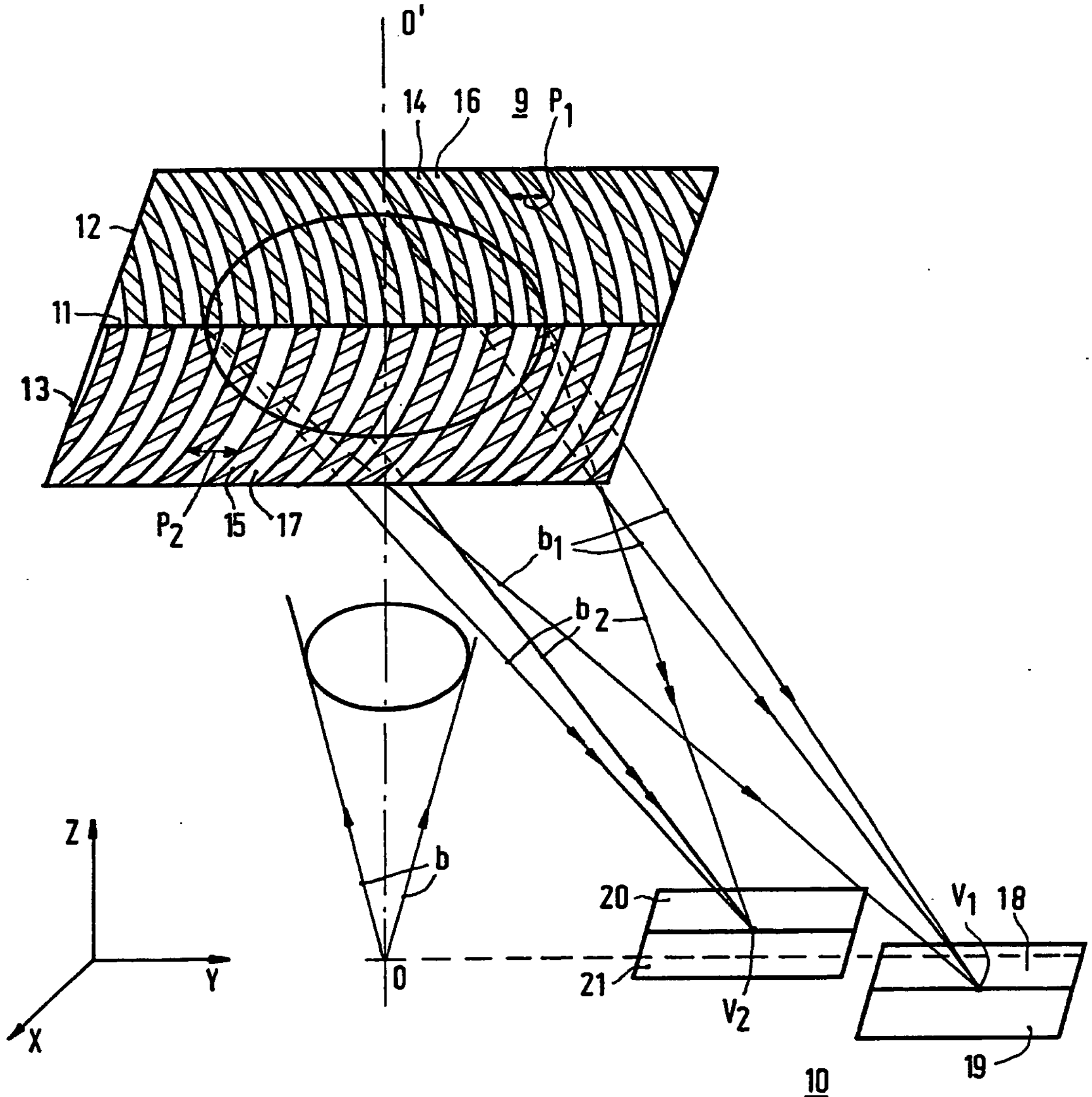

FIG. 8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 20 2734

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,X	EP-A-300570 (N.V. PHILIPS GLOEILAMPENFABRIEKEN.) * the whole document *	1-4, 6	G11B7/135 G11B7/09
P,Y		5	
Y	GB-A-2120493 (N.V. PHILIPS GLOEILAMPENFABRIEKEN.) * page 1, line 81 - page 2, line 3 * * page 3, lines 17 - 102; claims 1, 3; figures 3, 4 *	5	
X	EP-A-228620 (NEC CORPORATION) * the whole document *	1-4, 6	
Y		5	
A	EP-A-219908 (N.V. PHILIPS GLOEILAMPENFABRIEKEN.) * the whole document *	1-6	
A	US-A-4733065 (HOSHI ET AL.)		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G11B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05 FEBRUARY 1990	BENFIELD A.D.

3

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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T : theory or principle underlying the invention
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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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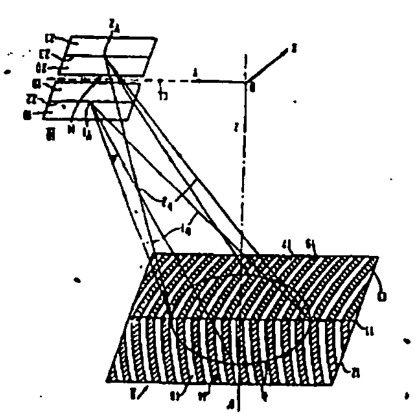
说明书页数：14 附图页数：6

[54]发明名称 对反光式信息面进行光扫描的装置

[57]摘要

描述一种用于对信息面2进行光扫描的装置，其中，透镜系统6把由二极管激光器4发射的光束b聚焦在该信息面上，并把由该表面反射的光束经由复合衍射光栅9聚焦成两个光点V_1和V_2，后者分别与分开的检测器对18、19及20、21合作。检测器对的分离条纹22、23是平行的，从而，在元件9、20的位置方面提供相当宽的公差范围。同时，该装置在光束b的波长变化方面得到令人满意的校正。



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权 利 要 求 书

1．一种对反光式信息面进行光扫描的装置，该装置包括：提供扫描光束的二极管激光器；用于使扫描光束在信息面上聚焦成扫描光点并使扫描光点在复合的辐射敏感检测系统上再成象的物镜系统；以及安装在二极管激光器和物镜系统之间光路中的复合衍射元件，该元件用于使由信息面反射的一部分光束向辐射敏感检测系统偏转并把所述偏转光束分裂成许多子光束，这些子光束在所述复合检测系统的相应的许多检测器对上形成相应的许多光点，与一个检测器对关联的两个检测器之间的分离条纹的取向使得由扫描光束的波长变化引起的再成象光点的偏移不会对检测信号有任何影响，其特征在于：

检测器对的分离条纹基本上平行于从二极管激光器的发光表面的中心的连接线。

2．如权利要求1中所要求的装置，其中，衍射元件是包括两个子光栅的衍射光栅，其特征在于：这些子光栅具有变化的光栅周期和弯曲的光栅条纹。

3．如权利要求1或2中所要求的装置，其中，衍射元件是包括两个子光栅的衍射光栅，其特征在于：

两个子光栅的光栅条纹具有相同的主方向，

两个子光栅的平均光栅周期是不同的，

各检测器对在平行于子光栅之间的边界线的方向上并置，以及

检测器对的分离条纹位于所述连接线上。

4．如权利要求1、2或3中所要求的装置，其中，衍射元件是包括两个子光栅的衍射光栅，其特征在于：

两个子光栅具有相同的平均光栅周期，

相对于两个子光栅的边界线，第一子光栅的光栅条纹的主方向以

第一角度延伸，而第二子光栅的光栅条纹的主方向以与第一角度反向的第二角度延伸，

各检测器对在所述边界线的方向的横方向上并置。

5．如权利要求1或2中所要求的装置，其中，衍射元件是包括两个子光栅的衍射光栅，其特征在于：

两个子光栅的光栅条纹具有相同的主方向，

两个子光栅的平均光栅周期是不同的，

各检测器对在平行于子光栅之间的边界线的方向上并置，以及

检测器对的各分离条纹以相对于所述连接线的、大约0．1°的大小相等、方向相反的角度延伸。

6．如权利要求1或2中所要求的装置，其中，衍射元件是包括两个子光栅的衍射光栅，其特征在于：

相对于两个子光栅的边界线，第一子光栅的光栅条纹的主方向以第一角度延伸，而第二子光栅的光栅条纹的主方向以与第一角度反向的第二角度延伸，

两个子光栅的平均光栅周期是不同的，以及

各检测器对在平行于所述边界线的方向上和垂直于所述边界线的方向上都处于不同的位置。

对反光式信息面进行光扫描的装置

本发明涉及对反光式信息面进行光扫描的装置，该装置包括：提供扫描光束的二极管激光器；用于使扫描光束在信息面上聚焦成扫描光点并使扫描光点在复合的辐射敏感检测系统上再成象的物镜系统；以及安装在二极管激光器和物镜系统之间光路中的复合衍射元件，该元件用于使由信息面反射的一部分光束向辐射敏感检测系统偏转并把所述衍射光束分裂成许多子光束，这些子光束在所述复合检测系统的相应的许多检测器对上形成相应的许多光点；与一个检测器对关联的两个检测器之间的分离条纹的取向使得由扫描光束的波长变化引起的再成象光点的偏移不会对检测信号有任何影响。

美国专利４，６６５，３１０公开了这种类型的装置，它在原则上适合于阅读记录在光记录载体上的信息，以及适合于对这种记录载体进行光学记录。在该装置中，衍射光栅式的复合衍射元件完成两种功能（在没有该复合衍射元件的情况下，这两种功能是由两个独立的元件完成的）。第一，该光栅确保由信息面反射并穿过物镜系统的光束偏离由二极管激光器所发射的光束的路径，使得能够在反射光线的路径中设置检测系统。第二，该光栅把被反射的光束分裂成产生聚焦误差信号（即，一种包含关于物镜系统焦面和该信息面之间偏移的大小和方向的信息的信号）所需的两束子光束。分开的检测器对与每束子光束相关联，同一检测器对的检测器的输出信号之间的差异是扫描

光束在信息面上聚焦程度的量度。

在所述记录载体中，信息是按照信息径迹排列的。如果两个子光栅之间的边界线平行于所述径迹方向，那么，通过测定每个检测器对的输出信号的和并且把这些和信号彼此相减，就能够获得包含关于扫描光点中心与要扫描的信息径迹中心轴之间偏移的大小和方向的信息的信号。

为实现所需的光束分裂，美国专利４，６６５，３１０的装置的光栅包括两个具有相同光栅周期的子光栅，同时，相对于两个子光栅的边界线，第一子光栅的光栅条纹以第一角度延伸、而第二子光栅的光栅条纹以与第一角度大小相等而方向相反的第二角度延伸。因为，衍射光栅使入射光束在横断所述光栅条纹的方向的平面内衍射，所以，投射到第二子光栅上的光束部分将获得不同的方向。

和美国专利４，６６５，３１０所述的一样，本发明中所述的光栅设计是以先前提出的复合衍射光栅作为根据的。后一种光栅包括两个子光栅，其中，一个子光栅的光栅条纹具有与另一个子光栅的光栅条纹相同的方向，但这两个子光栅的光栅周期不同。因为，入射光束在光栅上的衍射角度决定于光栅周期，所以，投射在所述两个子光栅上的光束部分以不同的角度衍射。

在包括这些光栅的扫描装置方面已经取得圆满的经验。但是，实验证明，在使用光栅时，由于扫描光束波长的变化，在产生聚焦误差信号中，可能发生偏差。确实，这种偏差可以保持在为该聚焦误差信号规定的公差范围内，但是，这将给其他可能的偏差留下很小的余地。例如，可能由于装置误差、光学元件彼此相对移动或电子处理电路的失调而出现上述其他偏差。

众所周知，实践中经常使用的二极管激光器所发射的光束波长可能由于例如温度的变化而变化。此外，在不同时刻制造而用在同一过程中的各个二极管激光器的波长可能彼此有差别。扫描光束的波长变化引起子光束在子光栅上的衍射角的变化，从而导致光点在所述检测对上位置的变化。

为了避免这种位置变化的影响所产生的聚焦误差信号，已经建议以如下方式排列每个检测器的分离条纹，即，由所述波长变化引起的光点偏移是沿着这些分离条纹发生的。

在英国专利4，665，310所述的装置中，这些条纹是有效的，即，当光束以相关的光栅的光栅条纹的横方向投射在该复合光栅上时，这些条纹是有效的。如果检测器对位于物镜系统光轴的一侧、并且、位于垂直于该光轴并与二极管激光器发光表面重合或平行的平面内，那么，所述分离条纹将以相对于两个检测系统的中心和二极管激光器的发光表面的中心的连接线的大小相等、方向相反的角度（＋ϕ，－ϕ）延伸。这种方法也可用于包括如下光栅的装置中，即，该光栅的子光栅具有不同光栅周期、而两个子光栅的光栅条纹的方向相同。

当使用具有倾斜的分离条纹的复合检测器时，必须非常精确地调整延着所述边界线测到的两个检测器对的中心和二极管激光器发光表面的中心之间的距离。

本发明的目的是提供开头一节中所述类型的装置，该装置在波长变化方面得到校正、并且、与其他装置相比、提供了关于所述光学元件的位置和参数的较宽的公差范围。

本发明的装置的特征在于：检测器对的分离条纹基本上平行于从

二极管激光器的发光表面的中心到复合辐射敏感检测系统的中心的连接线。

本发明基于所述扫描装置的新颖的设计思想。乞今的设计方法是：首先选择与除了复合检测器之外该装置的各元件的位置和参数有关的目标构形，然后，设计具有这样几何形状（特别是这样的分离条纹角度ϕ）的复合检测器，使得该装置在波长变化方面得到校正。本发明装置的设计方法是：首先从该装置的大致布局出发，设计具有给定几何形状的复合检测器，就波长变化和位置公差方面选定该检测器的最佳参数；然后，利用由该复合检测器为其他参数（尤其是各种光栅条纹的位置）提供的较宽的公差范围，完成该装置的设计。

本发明可以用于这样的扫描装置：在这些装置中，衍射元件由包括多个子光栅的光栅构成。这些子光栅可以具有直的光栅条纹和不变的光栅周期。但是，该装置最好具有如下特征：所述子光栅具有变化的光栅周期和弯曲的光栅条纹。

当使用具有变化的光栅周期的衍射光栅时，降低了对二极管激光器相对于光电二极管式检测器定位精度的严格要求，当必须减小沿物镜系统的光轴测得的该装置的高度时，这一点尤其重要。此外，当使用具有弯曲光栅条纹的光栅时，有可能通过修改复合光栅的曲率来校正诸如慧形象差和象散之类的成象误差，当使用具有直的光栅条纹的衍射光栅时，可能出现这些成象误差。

本发明的最佳实施例的特征在于：两个子光栅具有相同的平均光栅周期，同时，相对于两个子光栅的边界线，第一子光栅的光栅条纹的主方向以第一角度延伸，而第二子光栅的光栅条纹的主方向以与第一角度反向的第二角度延伸，并且，各检测器对在所述边界线的方向

的横方向上并置。

在本发明的装置的第二实施例中，复合光栅包括两个子光栅，该实施例具有如下特征：（１）两个子光栅的光栅条纹具有相同的主方向；（２）两个子光栅的平均光栅周期是不同的；（３）各检测器对在平行于子光栅之间的边界线的方向上并置；以及（４）检测器对的分离条纹位于所述连接线上。

该实施例在扫描光束的波长变化方面得到不完全的、但却是很大程度的校正，这种校正在许多情况下是足够的。为了得到完全的校正，检测器对的两条分离条纹必须以相对于所述连接线的、大约０．１°的大小相等、方向相反的角度延伸。原理上，可以把这种情况视为检测对的分离条纹基本上平行于所述连接线。

该装置的第三实施例的特征在于：（１）相对于子光栅之间的边界线，第一子光栅的光栅条纹以第一角度延伸，而第二子光栅的光栅条纹以与第一角度大小相等、方向相反的第二角度延伸；（２）两个子光栅的平均光栅周期是不同的；（３）各检测器对即在与所述边界线平行的方向上、又在与其垂直的方向上占据不同的位置。

下面将参考附图更详细地说明本发明的实施例，附图中：

图１用图解法示出包括衍射光栅的读出装置的实施例，

图２是本发明的检测系统和相关的衍射光栅的第一实施例的示意的透视图，

图３ａ和３ｂ表示当出现聚焦误差时在已知的检测系统中光点的变化，

图４示出用于图２的装置中的辐射敏感检测系统，

图５是所述装置的主要光路图，图中标出各可调参数，

图6示出检测系统和相关的衍射光栅的第二实施例，

图7是图6的检测系统的供选择的比较方案，以及

图8示出检测系统和相关的衍射光栅的第三实施例。

图1是具有反光式信息面2的光学记录载体1的一小部分的切线方向剖面图。该图示出一条位于信息面2中的径迹3。这种径迹包括与中间区3b相交替的信息区3a。例如，区域3a处在与中间区3b不同的高度上。该信息表面受到由二极管激光器4发射的光束b的扫描。该光束由物镜系统6（图上示意地用单透镜表示）聚焦，在信息面上形成微小的扫描光点V。如图1中所示，该物镜系统可以与准直透镜构成整体。另一种方法是，可以在该物镜系统的前面设置分开的准直透镜。当该记录载体绕平行于光轴OO的轴8旋转时，径迹3被扫描，从而，读出光束被包含在该径迹中的信息所调制。通过使记录载体和包括光源4、物镜系统6和检测系统10的读出头在径向（或X方向）彼此相对移动，使整个信息表面受到扫描。

应当检测已被信息表面反射和调制的光束，因此，必须将该光束与投射光束分开。所以，所述装置应当包括光束分离元件。

为了读出具有细微的、例如1微米量级的信息细节的信息结构，需要具有大数值孔径的物镜系统。这种物镜系统的景深是很小的。因为，可能出现信息面2和物镜系统6之间距离的变化大于景深的情况，所以，必须采取一些步骤以便检测出这些变化；并响应这些变化而校正聚焦。因此，该装置可以备有分束器（后者把反射光束分成两束子光束），并且，备有例如两个检测器对，其中第一对与第一子光束合作，而第二对与第二子光束合作。各检测器的输出信号经过处理后，除了别的以外，产生聚焦伺服信号。

正如在1980年12月15日出版的“新技术”第6期第3页上“光学聚焦误差检测”一文中所述的，光束分离和光束分裂可以用单一元件，即，透明光栅来完成。该光栅把由信息表面2反射并穿过物镜系统6的光束分裂成衍射的零级子光束和若干一级或更高级的子光束。这些光束之一（最好是一级子光束）投射到辐射敏感检测系统10、并特别用于产生聚焦误差信号。光栅的各参数，特别是光栅条纹的宽度与中间条纹的宽度的比例、以及光栅凹槽的深度和形状，可以按照能使最大量的光线到达检测系统这样的方式来选择。

图2是本发明的辐射敏感检测系统10和相关的光栅的第一实施例的透视立视图。用光束b在光栅9的区域上的横截面来表示该光束。光栅9包括被线11相互分开的两个子光栅12和13。子光栅12和13的光栅条纹分别用14和15表示。这些光栅条纹被中间条纹16和17隔开。在该实施例中，各子光栅具有相同的光栅周期，但是，子光栅12的光栅条纹14（最好是弯曲的）的主方向相对于边界线11以第一角度延伸，而第二子光栅13的弯曲的光栅条纹15最好相对于边界线11以与第一角度大小相等、方向相反的第二角度延伸。这些子光束b1和b2在XZ平面内以不同的角度衍射。这意味着在检测器平面上（XY平面），光点V1和V2沿X方向彼此相对移动。在该图和其他附图中，标记X、Y和Z是坐标系统的轴，该坐标系统的原点O与二极管激光器4的发光表面的中心重合。

由细条纹22和23隔开的光电二极管式辐射敏感检测器18、19和20、21分别与每束子光束b1和b2相关联。这些检测器要安置在适当的位置上，使得在光束b正确聚焦在信息表面2的情况下，由子光束b1和b2形成光点V1和V2的强度分布，对于检测器18、

19和20、21来说，分别是对称的。当出现聚焦误差时，光点V_1和V_2将变得较大和不对称，如图3a和3b中所示。这些图示出已知的复合检测器，即，一种这样的检测器：其分离条纹22和23分别以相对于点O和复合检测器10的中心M之间的连接线CL的角度$+\phi$和$-\phi$延伸，该连接线与图2和3中检测器对18、19和20、21之间的分离条纹24重合。图3a说明光束b的焦点位于信息面2前面的平面时的情形，而图3b说明光束b的焦点位于该信息面后面的平面时的情形。

如果检测器18、19、20和21的输出信号分别用S_{18}、S_{19}、S_{20}和S_{21}表示，那么，聚焦误差信号S_f将由下式给出：

$$S_f=(S_{18}+S_{21})-(S_{19}+S_{20})$$

正比于读出的信息的信号，即，信息信号S_i，由下式给出：

$$S_i=S_{18}+S_{19}+S_{20}+S_{21}$$

如果两个子光栅12和13的边界线11平行于读出径迹3的方向，那么，还可能通过检测器信号产生跟踪误差信号S_r。该信号由下式给出：

$$S_r=(S_{18}+S_{19})-(S_{20}+S_{21})$$

可以用如下方式确定该装置的尺寸，并使复合光栅的几何形状和扫描光束的波长彼此相适应，即，当扫描光束b的焦面与信息面2重合时，使子光束b_1和b_2聚焦在光电二极管对18、19、20和21的分离条纹上。此时，光点V_1和V_2的尺寸是最小的，并且，对于关联的检测器对来说，每个光点的强度分布是对称的。

当改变扫描光束的波长时，子光束被子光栅衍射的角度将变化。这意味着，对于每束子光束来说，该子光束的主光线投射在相关的光

电二极管对上的位置发生了偏移。为了保证主光线的这种偏移对聚焦误差信号没有任何影响，在已知的装置中总是保证这种偏移是沿着检测器对的分离条纹２２和２３发生的。因此，在上述实施例中，分离条纹２２和２３相对于点M和O之间的连接线以这样的角度$+\phi$和$-\phi$沿伸，以致这些分离条纹的延长线彼此相交于光轴OO'，如图３ａ和３ｂ中所示。为清楚起见，在这些图中，角度ϕ被夸大了。如果复合检测器的平面与二极管激光器４的发光表面（ＸＹ）重合，那么，所述延长线彼此相交于点O。

如果各分离条纹相对于连接线ＣＬ以角度ϕ延伸，那么，应当精确地调整复合检测器在Ｙ方向上的位置。当点M和O之间的距离Y_d变化时，各分离条纹相对于光点V_1和V_2的位置也变化，因此，这种变化将影响聚焦误差信号。确实，当使用具有弯曲的光栅条纹的复合光栅９时，可以通过移动该光栅来校正光点V_1和V_2位置，但是，只能在有限的程度上进行这种校正。

此外，当使用具有倾斜的分离条纹的复合检测器１０时，杂散光（例如，可能由于假反射而在该装置中产生这种光）可能以不同方式影响不同的检测信号，以致所导出的聚焦误差信号受到该杂散光的影响。事实上，这种杂散光束将投射在复合检测器１０的一部分上（例如，左侧部分），如图３ａ中用虚线园弧ＳＬ表示的。位于该园弧中的隔开的检测器的各部分具有不同的尺寸，因此，对于不同的检测器来说，所述杂散光对检测器输出信号的影响是不同的。

此外，如果检测器对１８、１９；２０、２１中的分离条纹２２、２３以这样的方式变化，即，该检测器对的各检测器具有不等的尺寸，那么，在代表作为聚焦误差的函数的聚焦误差信号的曲线中不仅可能

产生对应于合乎要求的聚焦状态的第一零点，而且，还可能产生不对应于合乎要求的聚焦状态的第二零点。于是，存在这样的危险，即，该装置的聚焦伺服系统将扫描光束的焦点调整到信息面2的上方或下方。

按照本发明，使用图2中以透视图表示的而图4中以平面图表示的检测器几何形状。

在图4的复合检测器10中，角度ϕ等于或基本上等于零；换言之分离条纹22和23彼此平行，并且，平行于分离条纹24和连接线CL。因此，降低了对点M和O之间距离Y_t的严格要求。此外，该装置因此而对复合检测器10相对于Y轴的倾斜不太敏感。

图4中，标记符号W表示复合检测器10的总宽度，而S表示检测器10的平面中光点V_1和V_2之间的垂直距离。如果扫描光束清晰地聚焦在信息平面2上，那么，垂直距离S是光点V_1和V_2所在位置之间的距离。两个检测器对18、19和20、21可以彼此相对排列，但相互隔开一定距离，如图4和图2中分别表示的。在复合检测器10设计中做了如下的考虑。

为了使检测器信号最佳化，希望不同的检测器具有相同的尺寸。如果检测器对彼此相对排列，那么，上述要求意味着W＝2S。W和S的取值是综合考虑的结果。一方面，为了使到达复合检测器10的杂散光的数量尽可能少，检测器10的宽度应当尽可能小。另一方面，为了使聚焦误差检测系统具有尽可能大的截获范围，W又应尽可能大。对于S来说，其值不应太小，这是由于在光点V_1和V_2的光线之间可能因此而出现干涉现象。实际上，这些光点不是点状的、有清晰边界的光点，而是稍微扩展的、其强度从中心向外侧降低的光点。另一方

面，S又不能太大，这是因为：以后在该装置的下一步设计中，看来很可能要在例如X和Y方向上移动光栅条纹（例如，光栅9），因此，可能出现象差，导致聚焦误差信号曲线零点附近的斜率变小。

具有平行的分离条纹的复合检测器的优点可能是：与具有倾斜的分离条纹的检测器相比，更易于以所要求的精度制作该检测器，尤其在距离S方面。

图5示出各种参数，在选择$\phi=0$的情况下，仍然可以在这些参数之间进行选择，以实现所希望的该装置的最优化。在该图中，认为二极管激光器4发光表面的中心位于坐标系统XYZ的原点。Y_d和Z_d是检测器10的中心M和点O之间沿Y轴和Z轴的距离。原则上，可以自由选择这些距离。实际上，最经常的情况是使用二极管激光器和光电二极管的组合体，这些元件安装在一个部件上，因此，Y_d和Z_d的选择受到限制。最好通过沿X和Y轴移动光栅9，并使它绕Z轴旋转，来确保光点V_1和V_2在复合检测器10上处于所希望的位置。

图6示出本发明的装置的第二实施例。在该实施例中，两个子光栅12和13的、最好是弯曲的光栅条纹的主方向相对于边界线11以相同的角度延伸，而两个子光栅的平均光栅周期是不同的。结果，子光束b_2在YZ平面的衍射角不同于子光束b_1的衍射角。这意谓着光点V_1和V_2在检测器的XY平面上沿Y方向彼此相对移动。

就其工作而言，图6的装置基本上类似于图2的装置，因此，不必予以描述。如果图6中的检测器10的分离条纹22和23彼此平行（$\phi=0$），如本发明中所建议的那样，那么，聚焦误差信号能够在实际上可接受的程度上与扫描光束的波长变化无关。如果在某些情况下希望进一步减小这种相关性的话，那么，可以使分离条纹22和

23相对于点M和O之间的连接线CL以非常小的角度ϕ（0.1°左右）定位，如图7中所示。由于角度ϕ的值非常小，所以，这种情况仍然在本发明的范围内。

应当指出，因为衍射光栅的效率（即，在所需要的方向上衍射光线的量与投射在光栅上的光线总量之比）特别依赖与光栅周期，所以，图2的复合衍射光栅比图6和7的更可取。实际上，由于图6和7的光栅的各子光栅具有不同的光栅周期的缘故，各子光栅可能获得不相等的强度，以致可能引起跟踪误差信号的失调。在使用图2的衍射光栅的装置中不会出现这类失调。

图8中示出本发明的装置的第三实施例。光栅9也包括两个子光栅12和13。但是，两个子光栅的、最好是弯曲的光栅条纹的光栅周期和主方向都不相同。可以认为这种光栅的工作是图2和6的光栅的工作的结合。结果，子光束b_1经由图8的光栅，在XZ和YZ两个平面中，以不同于子光束b_2的角度衍射。在复合检测器10的XY平面中，光点V_1和V_2在X和Y两个方向上彼此相对移动。显然，检测器对18、19和20、21也在X和Y方向上彼此相对移动。按照本发明，分离条纹22和23彼此平行，而该装置仍然在扫描光束b的波长变化方面得到令人满意的校正。

本发明可用于如下的任何聚焦误差检测系统中：其中，衍射元件用于把由信息面反射的光束和由二极管激光器发射的光束分离、并用于将反射光束分裂成多束子光束。实际上，几乎都采用由两个子光栅产生的两束子光束。在某些情况下，可能需要采用具有两个以上的子光栅的复合光栅，以便产生两束以上的子光束。本发明的方法可用于与这些子光束相联系的每个检测器对。这些光栅可以具有直的光栅条

纹和不变的光栅周期。但是，最好采用图2、6和8中所示实施例一类的光栅，这种光栅也称为全息图。这类光栅的子光栅具有变化的光栅周期，例如，该光栅周期以平均光栅周期的百分之几的数量级变化。此外，如图2、6和8中所示，两个子光栅的光栅条纹是弯曲的。因此，这些子光栅具有变焦距透镜的作用。由于变化的光栅周期的缘故，可以通过使光栅9在自身平面上移动来改变光点V1和V2的位置。可借助于各种光栅条纹曲率，在边界线11的方向的垂直方向上，把象差减至最小。当采用集成的激光器一光电二极管元件（即，在该元件中，二极管激光器和光电检测器设置在一个支承物上、因而彼此相对固定并在Z方向上具有不变的相对距离）时，移动光点V1和V2位置的可能性尤其重要。所述距离易产生制造公差，并且，不能在该装置装配期间，通过使光电二极管和激光二极管在Z方向上相对移动来加以校正。

在图6和8的实施例中，尽管由于子光栅12和13具有不同的平均光栅周期而使子光束b1和b2以不同的衍射角在YZ平面上衍射，仍然确保各子光束的焦点位于同一XY平面上，这是通过改变子光栅的相应部分的光栅条纹的曲率和光栅周期来实现的。

与具有直的光栅条纹的光栅相比，具有弯曲的光栅条纹的衍射光栅的重要优点在于：在具有弯曲的光栅条纹的光栅中，可以通过在制造这种光栅时考虑象差问题以及使光栅条纹的曲率适合于所述象差来消除诸如慧形象差和象散之类的光学象差，而当使用具有直的光栅条纹的光栅时可能出现这些光学象差。

上文已就本发明用于读出装置的情况做了说明，但是，本发明也可用于写入装置或组合式读一写装置，在这些装置中，记录期间，

对写光束的聚焦和跟踪进行监控。本发明所述的聚焦误差检测系统不要求信息面2具有特殊的性能。只要该表面是反光的就已足够。因此，本发明可用于需要非常精密的聚焦的各种装置中，例如，用于显微镜中，在这种情况下，可以省去跟踪误差检测。

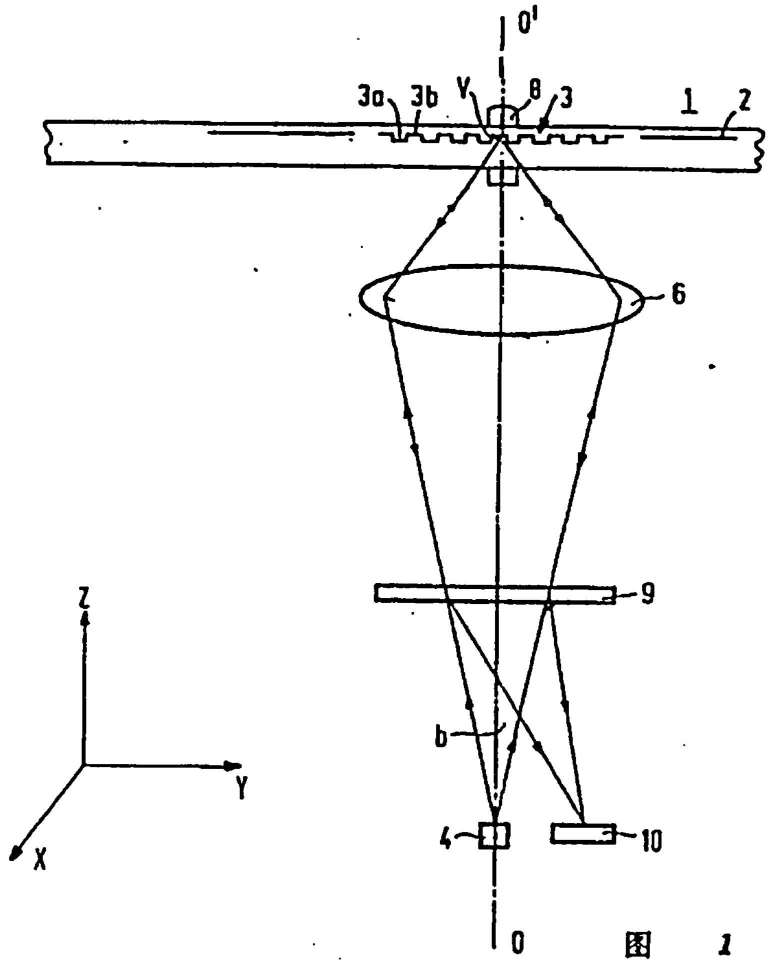

图 1

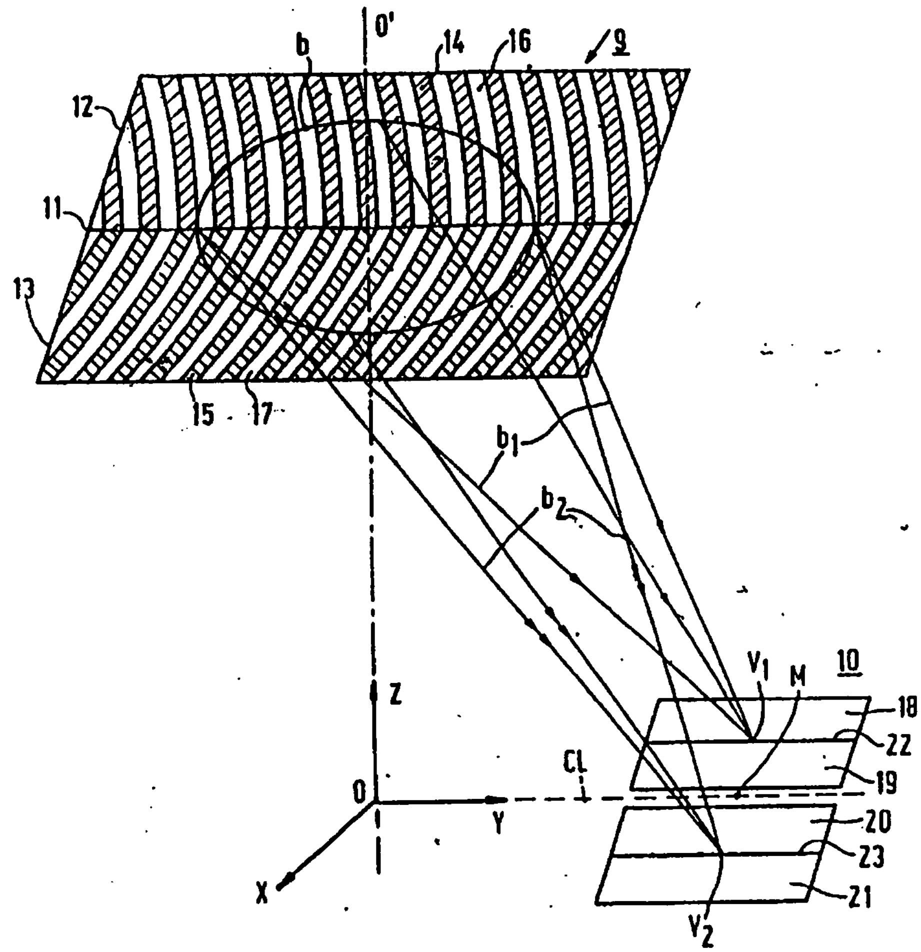

图 2

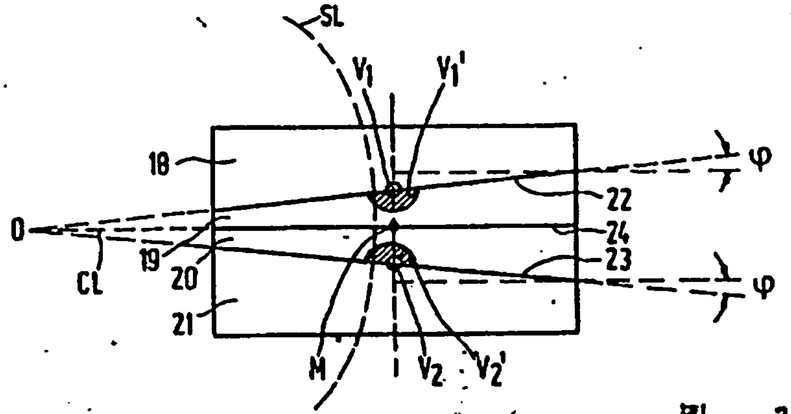
SL
V1
V1'
18
φ
22
0
24
19
23
CL
20
φ
21
M
V2
V2'

图 3a

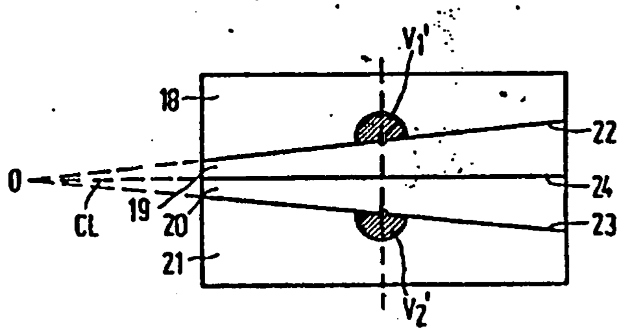
V1'
18
22
0
24
19
CL
20
23
21
V2'

图 3b

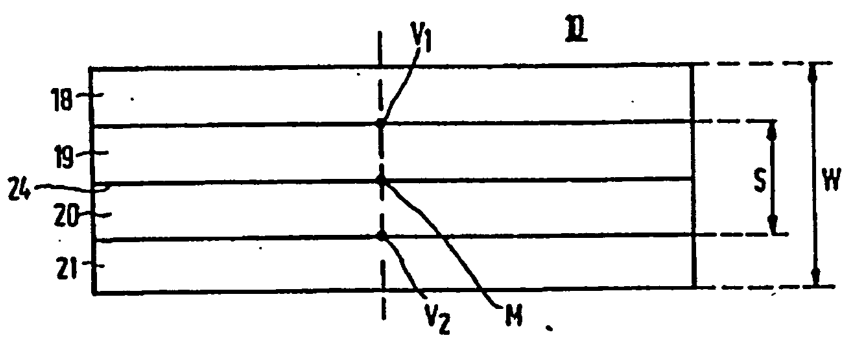
V1
D
18
19
24
S
W
20
21
V2
M

图 4

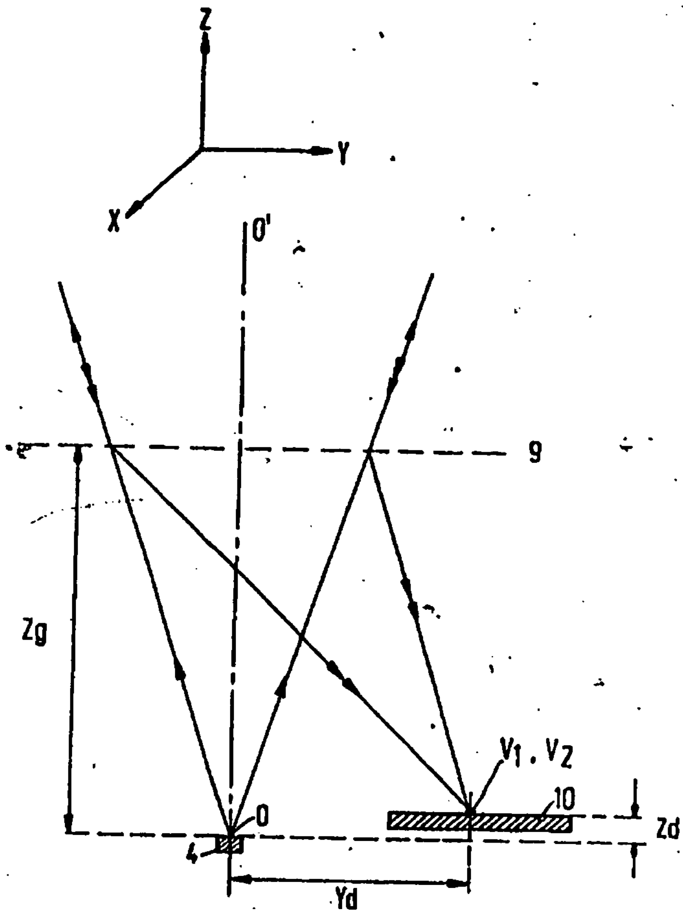

图 5

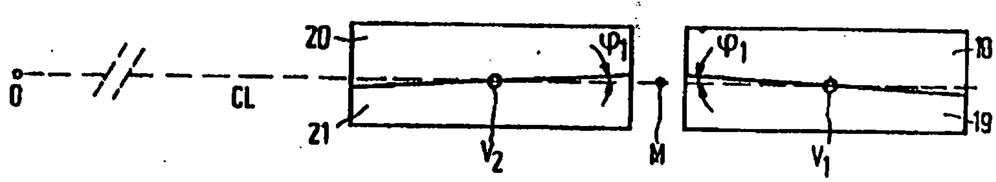

图 7

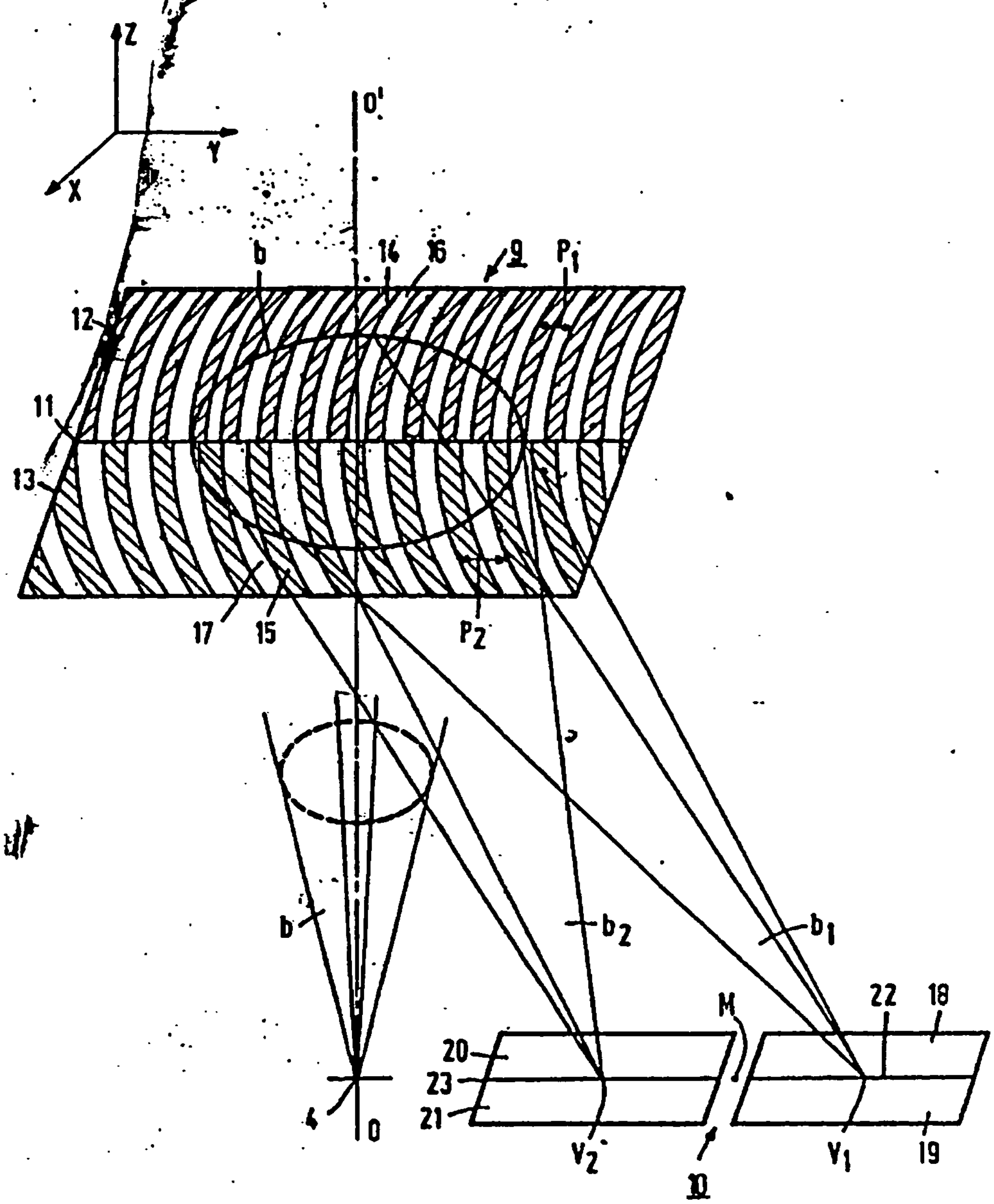
Z
Y
X
O'
b
14
16
9
P1
12
11
13
17
15
P2
b
b2
b1
M
22
18
20
23
21
4
O
V2
10
V1
19

图 6

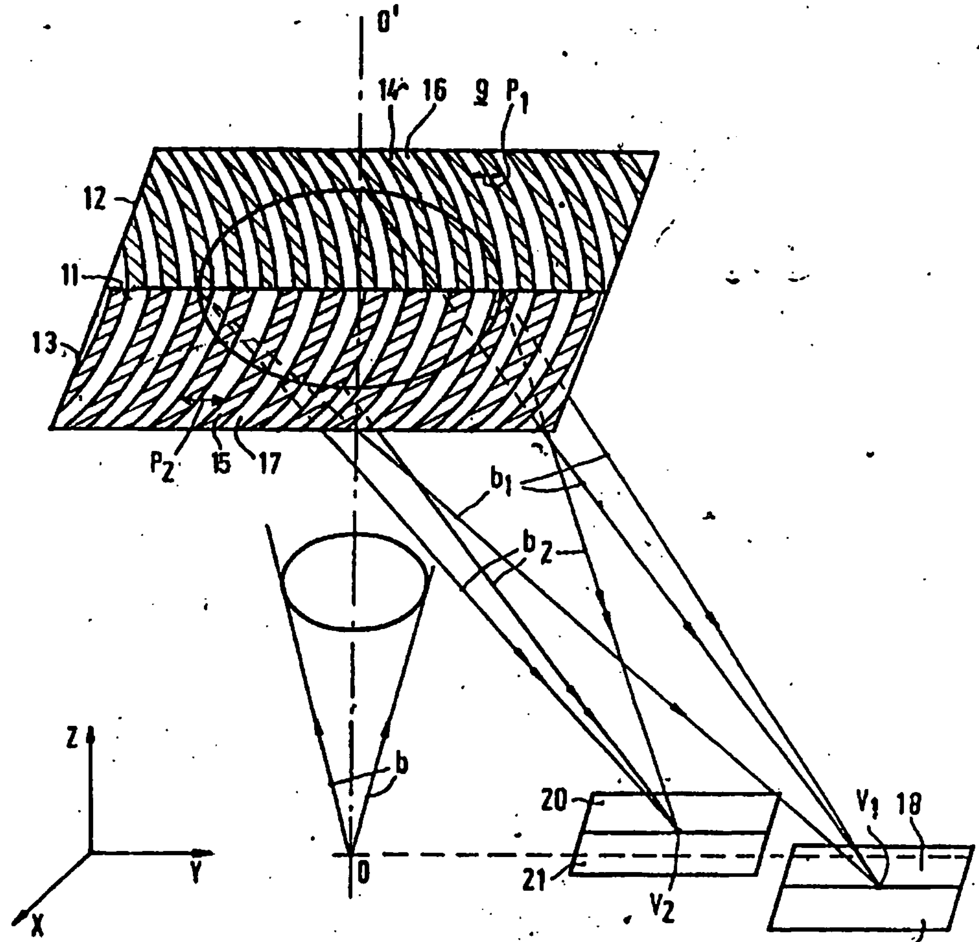

图 8